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Art. XV.—*Contributions to our knowledge of Australian Earthworms.*

The Blood Vessels—Part II.

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(With Plates XL.-XLII.).

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The present paper is a continuation of that previously published by me on the same subject (Proc. Roy. Soc. Vic., vol. xxii., pt. I., 1909), and has, like it, been undertaken in the Biological Laboratory of the Melbourne University, under the direction and advice of Professor Spencer. The bibliography is the same as before, and I have continued to employ the generic names given by Beddard in his "Monograph of the Order Oligochaeta" (from which also all the references in the text are taken) except in such cases as are indicated in which they have been altered in harmony with Michaelsen's later work.

The following is a list of the genera and species dealt with in the preceding paper:—

Cryptodrilus hulmei.
Digaster excavata.
Diporochaeta bakeri.
,, copelandi.
,, davallia.
,, richardi.
,, tanjilensis.
,, yarraensis.
Fletcherodrilus unicus.
Megascolex coxii.
,, dorsalis.
,, fielderi.
,, goonmurk.
,, tenax.[1]

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[1] Michaelsen uses this genus instead of Megascolides, "Die Fauna, Südwest Australiens," 1907, Oligochaeta, p. 160.

Woodwardia gippslandicus.
Perichaeta obscura.
,, manni.
,, macquariensis.
,, valida.

While those described in the present one are:—

Cryptodilus grandis.
,, manifestus.
,, saccarius.
Megascolex australis.
Notoscolex camdenensis.
,, queenslandica.

1.—**Megascolex australis,** Fletcher.

Perichaeta australis, Fletcher. Proc. Linn. Soc. N.S.W., vol. i., 1886.

Plate XL., Fig 1.

Dorsal vessel single, swollen in segments 15-10, and passing forward to the first segment, when it sends an exceedingly fine branch round the alimentary canal, which unites with the ventral on each side. In 15 and 16 it gives off two well marked vessels to the alimentary canal in each segment, while in 14 there is only one, and in 13 none at all. In 12, 11 and 10, a pair of *hearts* arise in the hinder part of each segment, whose connections with the dorsal vessel are so small as to be only discernible in serial sections, the hearts arising from a very definite *supra-intestinal*, which takes its origin as a separate vessel over the alimentary canal in 13, and which runs forward to end blindly over the same organ in 9. From 9-6 distinct commissurals pass from the dorsal at the hinder end of each segment to the ventral vessel, sending a branch to the posterior septum and ventral body wall. From 5 forwards these vessels are very small, and hard to trace among the exceedingly strong muscles, but there is apparently one leaving the dorsal and entering the ventral in each segment. In 5, that from the dorsal breaks up into fine capillaries, about half way down the segment, which appear to connect with another set associated with the anterior end of the *lateral vessel*, but their direct continuity is hard to make out. The lateral runs backwards, sending a branch to the posterior septa of the segments in 6-9, and passing below the alimentary canal as the sub-intestinal in 10-13, on the hinder septum, of which last segment it ends. It receives branches from the calciferous glands, apparently derived from the supra-intestinal in 10, 11 and 12, and others from the alimentary canal, whose origin is less obvious in 13 and 9, giving branches to the posterior system of the segment in 10, 11 and 12.

The ventral is a single vessel, not clearly marked in the anterior segments, giving branches to the ventral body wall in each posterior to 13, and joining the dorsal as described. The difficult point to explain is the slight connection between the hearts or supra-intestinal vessel with the dorsal, the only truly functional branches arising from this in the region of the hearts being those to the posterior septa of the segments, and these are so small as to be best made out from sections.

The explanation seems to be found on an examination of a series of sections passing from segment 9 to about segment 15 or 16. The dorsal vessel is greatly expanded in the segments immediately posterior to the hearts, its walls having the typical structure described by Beddard (p. 65), consisting of an epithelial wall surrounded by circular and longitudinal muscles. This vessel, evidently well fitted for pumping action, gives marked vessels to the alimentary canal as described, but from this organ the blood is passed to the ventral by very insignificant branches. It must therefore pass along the alimentary canal in the sinus-like vascular space surrounding it, to be collected to the definite supra-intestinal vessel in 13: and the pumping force of the dorsal vessel must be strong enough to pass it forward till it reaches the hearts, where fresh propulsion will take place, since the connections of these vessels with the dorsal are so small as to be negligible from a functional point of view. The supra-intestinal, though not a very large vessel, has, in the region of the calciferous glands, fairly muscular walls, which would be capable of propelling the blood, but this theory does not explain the more than usually muscular walls of the dorsal vessel in this region.

2.—**Notoscolex camdenensis**, Fletcher.[1] Proc. Linn. Soc. N.S.W., vol. i., 1887.

Cryptodrilus camdenensis, Fletcher.

Plate XL., Fig. 2.

Dorsal vessel single, swollen in segments 17-14, less so in 13-10. It passes forward to 1, where it apparently breaks up; but from 4-1 the muscles are very thick, and in these segments the connections between the dorsal and ventral, if present, are indistinct. In 17-14 the dorsal gives clear vessels to the calciferous glands, and posterior to these in each segment one or two branches to the alimentary canal, whose connections with the ventral are small, and barely to be made out even in sections. From 9-6 a pair of commissural vessels arises from the dorsal at the hinder end of each segment, showing some distance along their course a construction probably due to the presence of a valve. From this point (which is higher than in the other vessels) in 6, arises a *lateral* passing backwards, and closely applied to the alimentary canal. Below the valve the commissurals give branches to the posterior septa of the segments, there being many of these vessels in 6. The lateral is fairly distinct in 7, 8 and 9, closely applied to the alimentary canal, receiving vessels from it, and sending branches to the posterior septa; but in the region of the hearts it becomes indistinct, and only apparent as the *sub-intestinal* on each side in sections, where it is seen to end in the sinus around the alimentary canal in 13, sending small branches to the posterior septa in 10-13. *The hearts* are four pairs, in segments 10-13, arising mainly from the *supra-intestinal*, but each receiving a small branch from the dorsal. They are somewhat monilform in appearance, and fine at their junction with the ventral, and in section are found to contain valves, which have also been noticed in the hearts of other worms. (See Beddard, p. 73.)

The supra-intestinal arises as a definite vessel from the sinus around the alimentary canal in 13, and passes forwards to end above that organ in or about segment 9. It is the main origin of the hearts, as has been said, though it becomes rather indistinct between them, and is connected with the large sinus around the alimentary canal in this region, though not by very definite vessels, passing to the sub-intestinal.

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[1] Michaelsen retains Fletcher's genus Notoscolex "Die Fauna, Südwest Australiens," 1907, Oligochaeta, p. 162.

The ventral is single, and passes forward to where it breaks up into fine branches, which may or may not join the dorsal. In 2 it sends branches to the alimentary canal, and behind the heart region a vessel to the posterior septum and ventral body wall in each segment. As has been said, the connection between the dorsal and ventral by way of the alimentary canal is indistinct. This, however, is common, as Beddard (p. 72) remarks that in earthworms the commissurals are confined to the anterior segments of the body, but in the embryo of Lumbricus each segment has a pair of commissurals. Evidently, therefore, it is better to call these vessels in the hinder regions of the body dorso-intestinal.

3.—**Notoscolex queenslandica,**[1] Spencer.

Cryptodrilus queenslandica, Spencer. Proc. Roy. Soc. Vict., vol. xiii., pt. i., 1900.

Plate XL., Fig. 3.

Dissection.—Dorsal vessel single, swollen in segments 18-10, and giving off distinct dorso-tegumentary vessels to the hinder mesenteries in those posterior to the hearts. The tegumentary blood system is very well marked along the whole length of the body. The alimentary canal in the intestinal region is well supplied by large vessels arising from the dorsal which apparently end blindly : but in the segments immediately behind the hearts, which have vascular swellings in 16 and calciferous glands in 14 and 15 (Spencer, loc. cit.), these vessels end in a blood sinus below the alimentary canal. The commissurals, if present, are very indistinct along the intestinal region. The dorsal runs forward to the first segment, when it breaks up into very fine branches after giving off a small vessel connecting with the lateral. From 9-2 the dorsal gives rise to a pair

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[1] Michaelsen, loc. cit., p. 162.

of commissurals in each segment, which pass to the ventral vessel, sending a branch to the ventral body wall and posterior septum of the segment on the way. In 4, 3 and 2, however, the commissurals are very fine, and the vessel to the body wall not apparent, though in 3 there is a large development of branches over the alimentary canal and gland. From 9-5 these commissurals present a constriction, probably marking a valve, about one-third of the distance along their length; and from this point vessels arise running to the alimentary canal wall, and in 5 to the hinder septum of the segment.

In 10, 11 and 12 are a pair of *hearts*, thrown into folds by strong connective tissue, and passing to join the ventral. They are connected with the dorsal by a fine vessel at the posterior part of each segment, but their main origin is from the well-marked *supra-intestinal*, which arises in 12 and runs forward to end over the alimentary canal in 7. It gives off well-marked vessels to the alimentary canal in 12-7, which send branches to the posterior mesentery of the segment, and join the lateral. These branches to the mesenteries are more marked in the segments anterior to the hearts.

The *lateral* is a well-developed vessel along the whole of its length, taking origin in the first segment on the dorsal side of the body, where it breaks up into very fine branches, one of which connects with the dorsal on each side. It sends irregular branches over the alimentary canal in 1, 2 and 3, and in 4 becomes larger, giving well-marked vessels to the posterior septum. From 4 it runs backwards as a very distinct vessel, whose branches to the hinder septa of the segments are very large, and run in close connection with the lower parts of the commissurals in 9, 8, 7 and 6. In 6 and 7 it is connected with its fellow of the opposite side at the anterior end of the segment by a vessel below the alimentary canal (which sends a branch to the anterior septum), and in 5 and 6 it gives branches to this organ, while from 7-12 these are connected also with the supra-intestinal, though there are also smaller branches passing only to the lateral. In 10 the lateral passes below the alimentary canal, and becomes the *sub-intestinal* on each side, receiving branches from the supra-intestinal in 10, 11 and 12, and giving vessels to the posterior septum. It then runs on, receiving a small vessel from the dorsal in 13, and ends on the ventral body wall in 16.

The *ventral vessel* is not very well developed anteriorly to 13. It receives a commissural in each segment, and breaks up into very fine branches in 1, some of which pass to the dorsal surface and appear to form very fine connections with branches of the lateral. Behind 14 the ventral is small, and sends branches to the body wall in each segment. In section it appears to be connecting with a sinus around the alimentary canal by extremely small vessels. This sinus is supplied by well-marked vessels from the dorsal.

Both dorsal and ventral vessels are unusually thick-walled and muscular in the hinder region of the body.

4.—**Cryptodrilus manifestus**, Fletcher. Proc. Linn. Soc. N.S.W., 1888.

Plate XLI., Fig. 4; Plate XLII., Fig. 7.

Dissection.—*Dorsal vessel* single, slightly swollen in segments 13, 14 and 15, and running forward to apparently break up in 1.

From 15 backwards it gives off two vessels in each segment closely applied to the alimentary canal. In 14 there is apparently only one of these, while in 13 none arises from the dorsal at all.

In 10, 11 and 12, a pair of *hearts* arise from a double origin at the posterior part of each segment, and pass to the ventral vessel. From the hinder end of segments 9-5 a pair of *commissurals* arise, running parallel to, if not joining with, the lateral or one of its branches for some distance in each segment. and sending vessels to the posterior septum and ventral body wall before joining the ventral. The mesenteries anterior to 7 are very thin, which makes the segmental arrangement difficult to distinguish, but in 5 the commissural gives branches to the alimentary canal as well as those already described for each segment. Anterior to 4, the vessels are small and indefinite. but the dorsal appears to give branches to the alimentary canal and break up in 1.

The ventral vessel is also single, sending branches to the alimentary canal in the segments anterior to 4, and to the ventral body wall from 6 to 1, in which it breaks up. From the anterior end of 10 passing backwards, it gives branches to the ventral body wall, especially well-marked in 10, 11 and 12.

There is apparently *no supra-intestinal*, but in 10, 11 and 12 is a short *transverse vessel*, which is the main origin of the hearts. There is a well-marked branch from this vessel in each segment, also to the calciferous glands, which is connected with the lateral; and vessels pass to the dorsal surface of the alimentary canal, running forward in each of the three segments, but with no definite connection with the transverse vessel of the next. Even in sections, which show the blood supply is thick above the alimentary canal, no definite supra-intestinal can be made out; the only approach to it being between 12 and 13, where a median vessel, apparently taking origin from the irregular blood spaces and in connection with those of the calciferous glands of each side, passes forwards to unite with the transverse of 12.

The lateral arises from the commissural in 5 on each side, and runs forward to break up on the anterior septum of that segment, passing back to join its fellow at the posterior end of 9, through (in one specimen) a glandular organ, from whence it runs on as a single *sub-intestinal*, dividing again at the hinder end of 12, and ending on the posterior septum of 13. From 5-9 its branches pass to the alimentary canal and posterior septum of each segment, the latter vessel having in most cases, as stated, a curious connection with the commissurals which seems to only involve the outer coats of the vessels.

5.—**Cryptodrilus grandis**, Fletcher. Proc. Linn. Soc. N.S.W., 1887.

Notoscolex grandis, Fletcher.

Plate XLI., Fig. 5.

Dissection. Dorsal vessel single, very slightly swollen in the heart region, running forwards to segment 1, where it divides to two, one passing round to join the ventral on each side.

From 15-20 it gives off a pair of vessels in each segment, supplying the alimentary canal, but their connections with the ventral (if any) have not yet been made out. Behind the wall opening it continues to give rise to a pair of vessels closely applied to the alimentary canal wall on each side in every segment, but their further relations need microscopically examining. In 14 the dorsal gives off one branch to the sub-intestinal, supplying the alimentary canal on its way, and from the back of 13 a pair of *hearts* arise, with a double origin—from the dorsal and supra-intestinal—and run round to the ventral vessel, joining it on its under side, this arrangement being continued till segment 10. As far as can be seen microscopically there are valves in the dorsal vessel at each septum, and also at the origin of the hearts. From 9-2 the dorsal gives off from the hinder part of the segment a pair of *commissural vessels* on each side, and from 9-5 definite branches arise from these to the posterior septum of each segment. The mesenteries in this form are exceedingly thick at the anterior end, and with this fact may probably be associated the great development of small branches arising from all the main vessels in this region. In 4 the commissurals give off on each side a *lateral*, running backwards and forming later on, as usual, the *sub-intestinal*, which seems to end as a marked vessel at the posterior part of 15, but to run on somewhat indefinitely for a short distance behind this. From all around the origin of the lateral, and from the two pairs of commissurals in 2 and 3, small branches arise, supplying the anterior end of the alimentary canal, salivary glands, etc. The lateral gives a definite branch to the hinder septum of the segment in 5-13, which is not so marked in the heart segments as elsewhere ; while there is a particularly large development of branches over the upper portion of the alimentary canal in 9. From 6-15 the sub-intestinal receives vessels from the alimentary canal.

The *supra-intestinal* arises in 14, and is double in this segment, and as far as the middle of 13 in the specimen examined. It seems to take origin just where it sends branches to the alimentary canal, and from here forwards as far as 8, it sends a pair of vessels in each segment to supply this organ, and open to the sub-intestinal ; while in 6 and 7 it gives smaller branches to the alimentary canal above which it ends blindly in 6.

The ventral vessel runs forwards and breaks up at the anterior end, sending a branch to join the dorsal as described, and behind the region of the hearts it gives a very definite pair of vessels in each segment and the ventral body wall running along the septum.

6.—**Cryptodrilus saccarius,** Fletcher. Proc. Linn. Soc. N.S.W., 1887.

Plate XLI., Fig. 6, and Plate XLII., Fig. 8.

Dorsal vessel single, slightly swollen in segments, 14-10. It passes forwards to first segment, becoming very indefinite in the anterior two or three, but apparently joining the ventral in 1. From 14 backwards it gives off a commissural vessel on each side, which supplies the alimentary canal, but in all cases in this form the connections with the ventral vessel are fine. There are four pairs of *hearts*, the last arising in the posterior part of segment 13, from a double origin—by a fine branch from the dorsal and a much more definite one from the *supra-intestinal.* This latter makes its appearance in segment 13, and is very marked, giving large branches to the calciferous glands, which are conspicuous structures, in segments 13-9. It apparently becomes discontinuous in segment 12, but on examining microscopically, is found to be represented by an exceedingly fine vessel between the hearts in 11 and 12. It ends blindly above the alimentary canal in segment 8.

From segment 9 forwards the dorsal gives off a pair of commissural vessels at the posterior part of each segment, that in 9 being very well marked. From 9-6 the commissurals give branches to the posterior septum of the segment, that in 6 being small. Those commissurals in 2, 3 and 4 are very indistinct, but apparently join the ventral vessel, while that in 5, after giving a branch to the alimentary canal, joins a marked *lateral*, which in its turn sends a branch to the ventral vessel. It also joins its fellow of the opposite side under the alimentary canal in segment 5, and sends a branch forward to the alimentary canal wall. The excessive development of blood vessels is a marked feature of this segment, and is probably associated with the well-marked "salivary gland." The commissural in 4 also sends a branch back to break up on the alimentary canal.

The *lateral* is very large at its origin, though its connection with the commissural is somewhat faint. It runs backwards, sending branches to the posterior septum of the segment in 6, 7, 8 and 9, and in 9 receives vessels from the calciferous gland. In the anterior part of 10 it joins its fellow of the opposite side by a single vessel, and from this point two continuations of the laterals run back closely applied to the ventral wall of the alimentary canal, and forming the *sub-intestinals*. In 10, 11, 12 and 13 vessels from the calciferous glands open to these.

The *ventral* vessel is single along its length, and becomes inconspicuous at its anterior end. In the region of the calciferous glands, which are really highly vascular enlargements of the alimentary canal, the branches from the supra-intestinal are closely applied to the wall of the gland, and send vessels to its villus-like projections on the internal surface of the gland. The blood is then collected up with definite vessels (Br. Cal.), passing to the sub-intestinal on each side. (See Fig. 8.)

EXPLANATION OF PLATES XL.-XLII.

Figs. 1-6.—Diagrams of side views of the cephalic blood vessels of the earthworms named.

Fig. 7.—Dorsal view of the vessels at the origin of one of the hearts in *C. manifestus*.

Fig. 8.—Low power view of the blood supply to and from a calciferous gland of *C. saccarius*.

REFERENCE LETTERS.

Al. C. - -	Alimentary canal.
B. - - -	Branch from ventral vessel to septum and body wall.

B. A. - - Branch from commissural vessel to alimentary canal.
B. C. - - Branch from commissural vessel to septum.
B. D. - - Branch from dorsal to heart.
B. S. - - Branch from sub-intestinal or lateral to septum.
Br. A. - - Branch from supra-intestinal to alimentary canal.
Br. Cal. - Branch from calciferous gland to sub-intestinal.
br. Cal. g. - Branch from supra-intestinal to calciferous gland.
Br. W. - Branch from commissural to septum and body wall.
D. S. - - Branch from dorsal to septum.
D. V. - - Dorsal vessel.
Ht. - - Heart.
Mes. - - Mesentery.
Pl. - - Plexus on alimentary canal.
Pl. S. - - Branch from plexus to septum.
S. I. V. - Supra-intestinal vessel.
Sub. I. V. - Sub-intestinal vessel.
V. V. - - Ventral vessel.